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(56) Documents cited
GB 2149258 A GB 2127649 A GB 1310659 A
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(58) Field of search
UK CL (Edition J) H4F FESG FESX
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(54) Image transformation apparatus

(57) The image captured by a video camera 2 mounted at a fixed position is transformed to give the effect of moving the camera by rotation of the image plane modelled in a 3-dimensional space. The model of the plane is created 5 in dependence on the angle of the camera with respect to the object W to be imaged. Input means 11 indicate the new view-point, and cause memory controlling means 8 to carry out appropriate mapping of image singals from input memory 9 to output memory 13. Correction means 12 may apply distortions to selected parts of the image, eg to compensate for the difference in appearance of a tree from above and from the side.
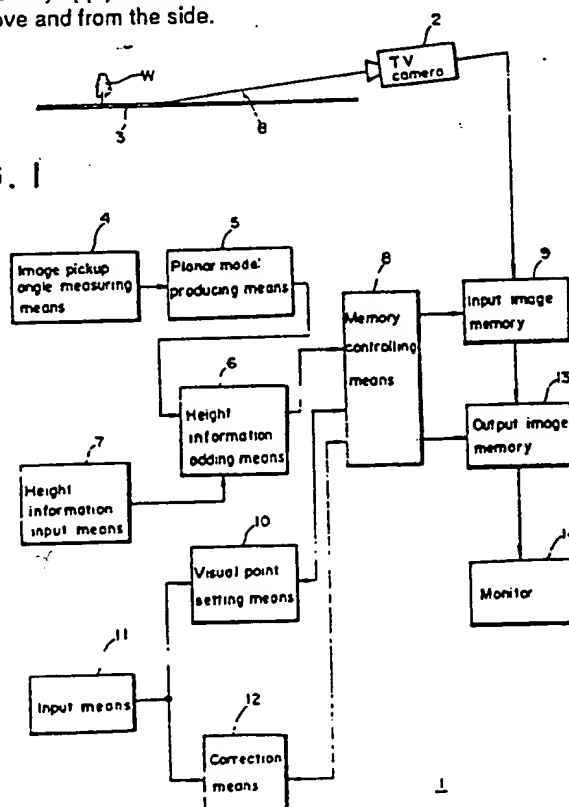
FIG. 1

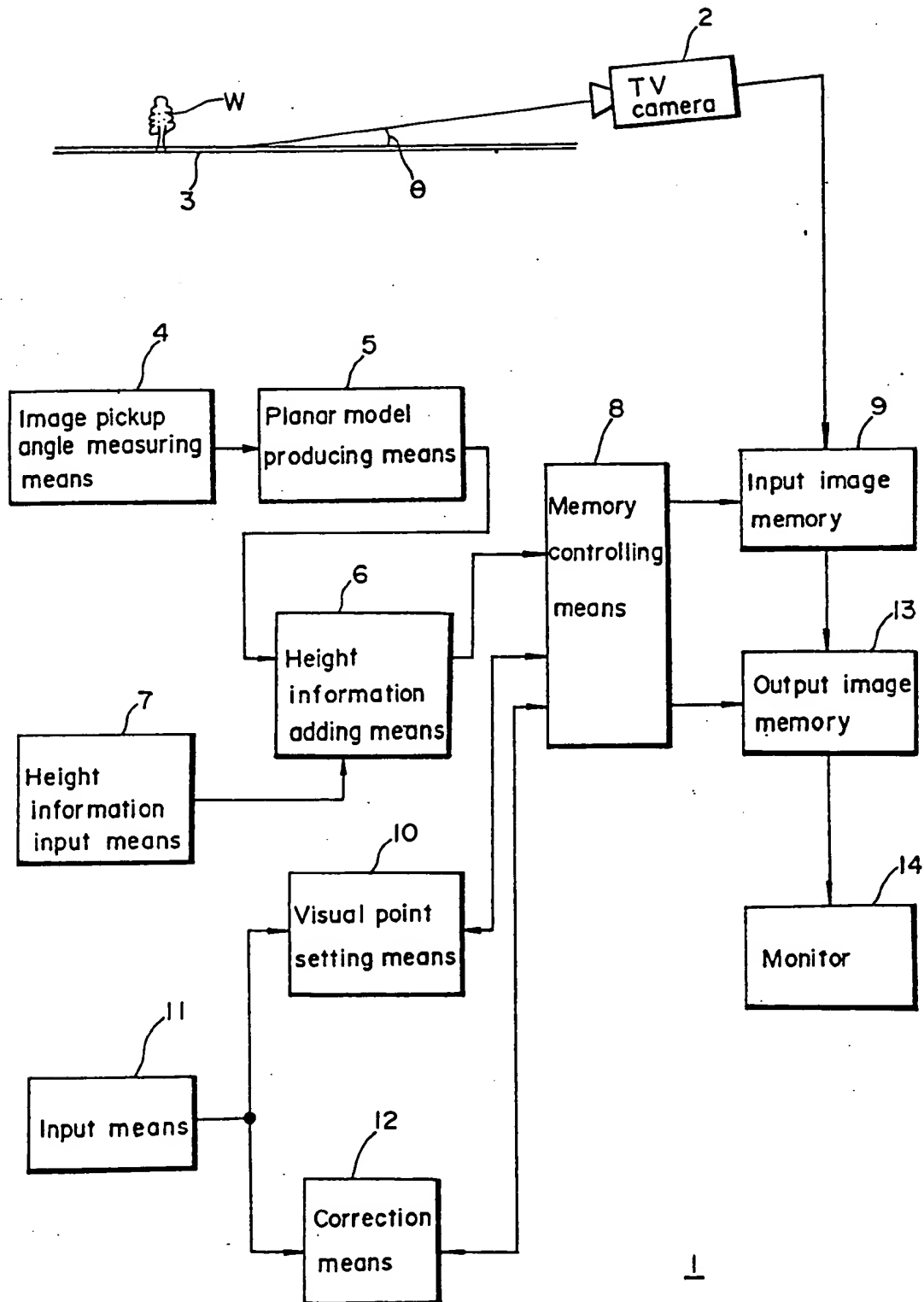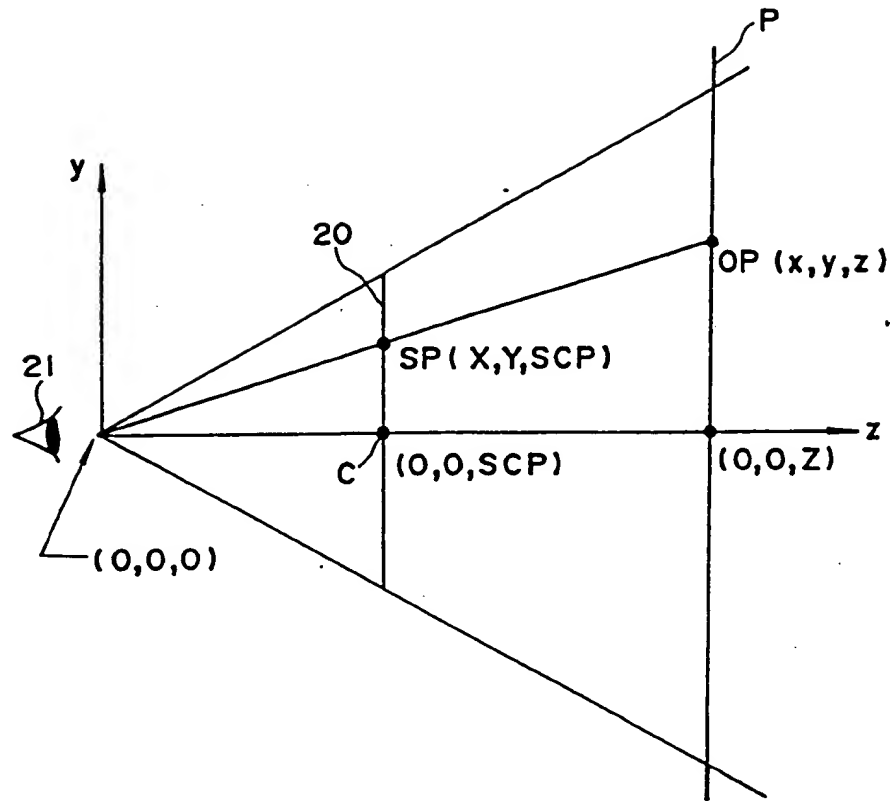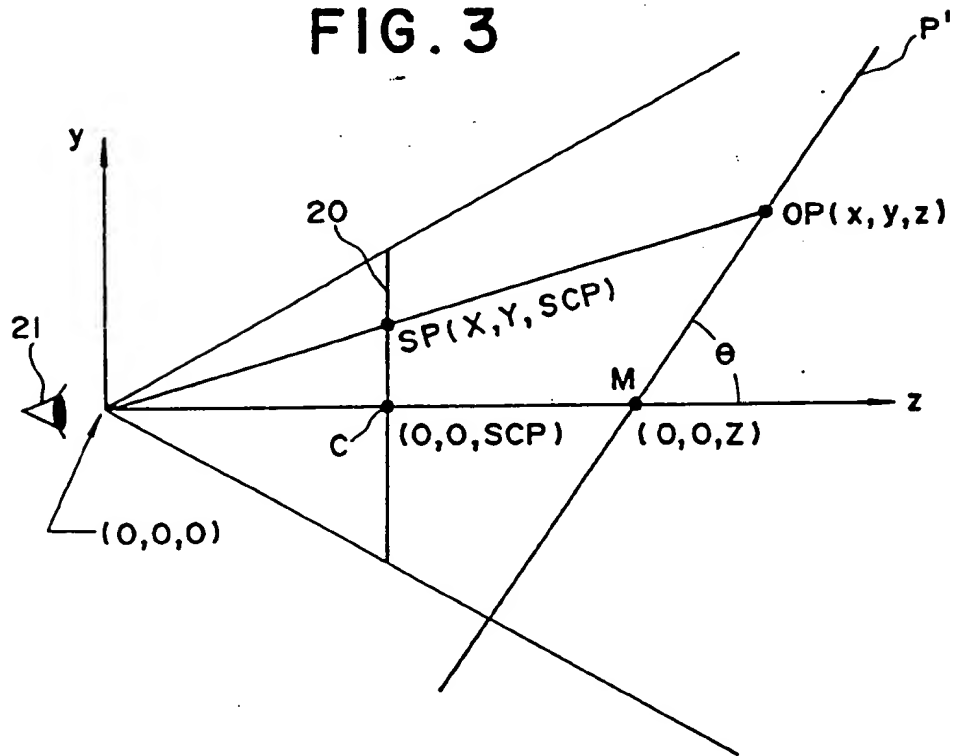Best Available Copy

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FIG. 1

FIG. 2

FIG. 3

FIG. 4

W

T

FIG. 5

W

T
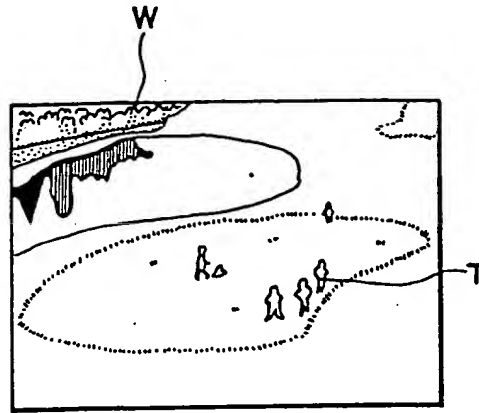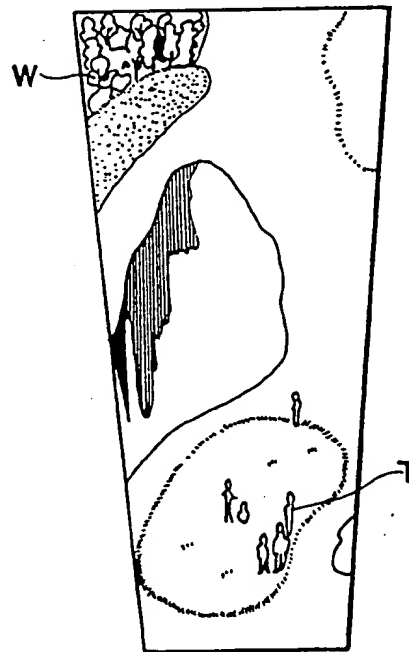
FIG. 6A
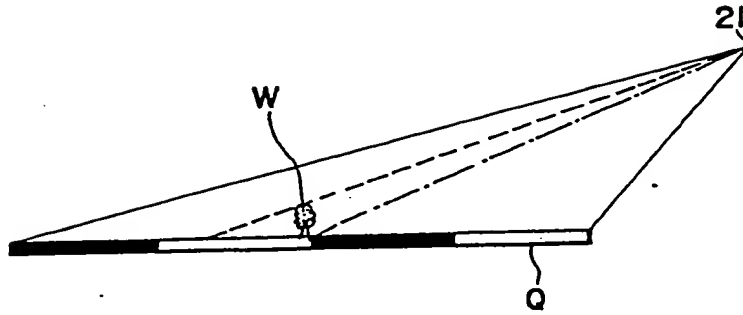
FIG.6B
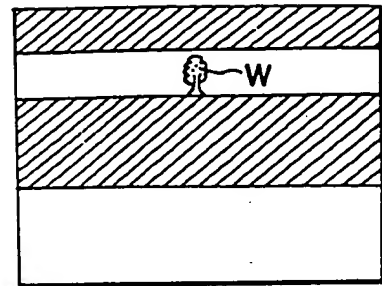
FIG. 6C

FIG.6D

FIG.6E

FIG.6F

FIG. 7

W

T

FIG. 8

2

$h(u,v)$ θ   Q'
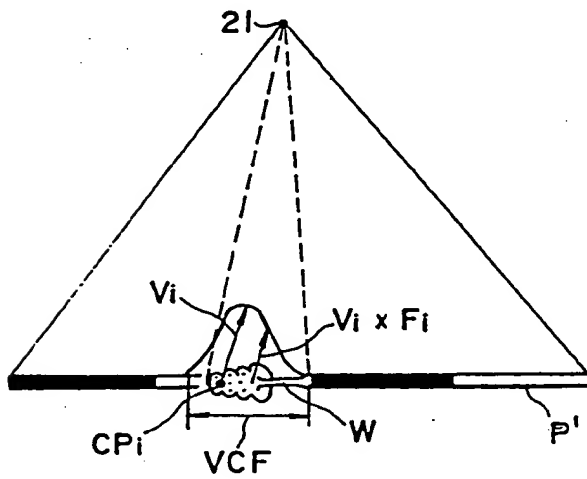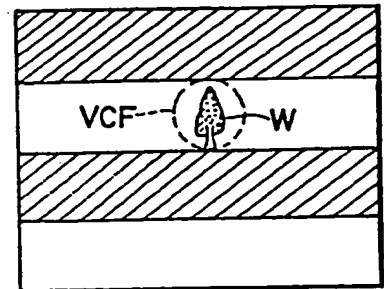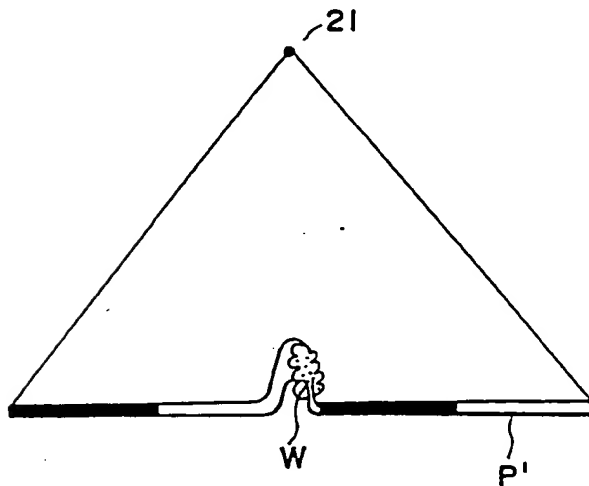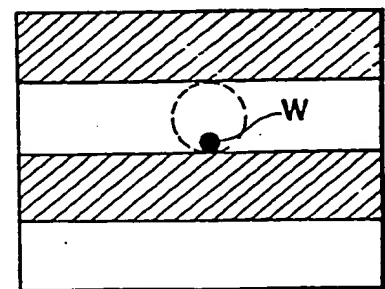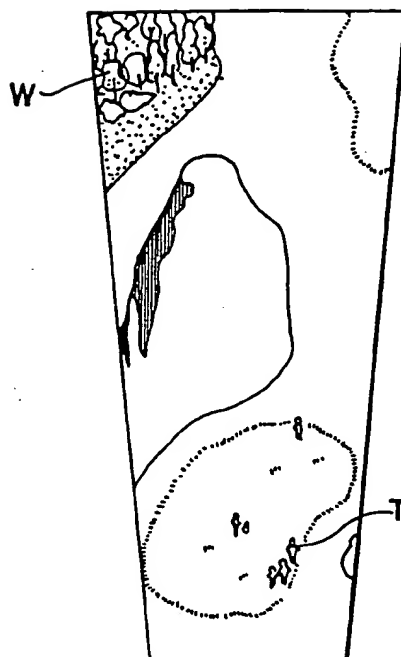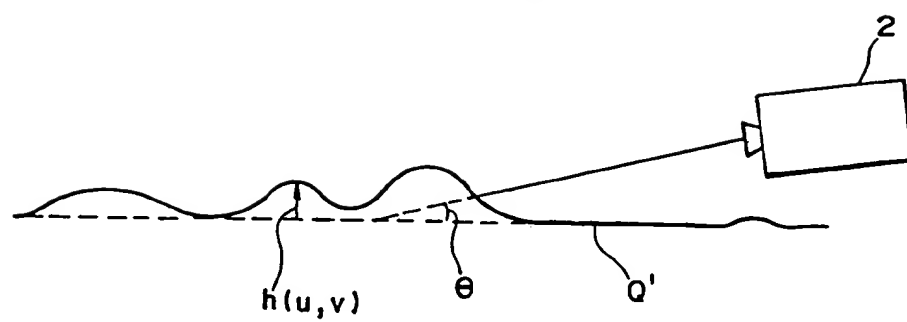
FIG. 9

FIG. 10

FIG. II

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START —SP1

Measure image
Pickup angle —SP2

Produce planar model
from three equations —SP3
(5)(6)(7)

Height
information
available?   SP4

— YES → Add height information
to planar model —SP5

— NO

Map video signal from
TV camera onto model —SP6

Local
correction —SP7

Correction
completed?   SP8

— NO

— YES

Set positon of
visual point —SP9

Position
of visual point
satisfactory?   SP10

— NO

— YES

END —SP11
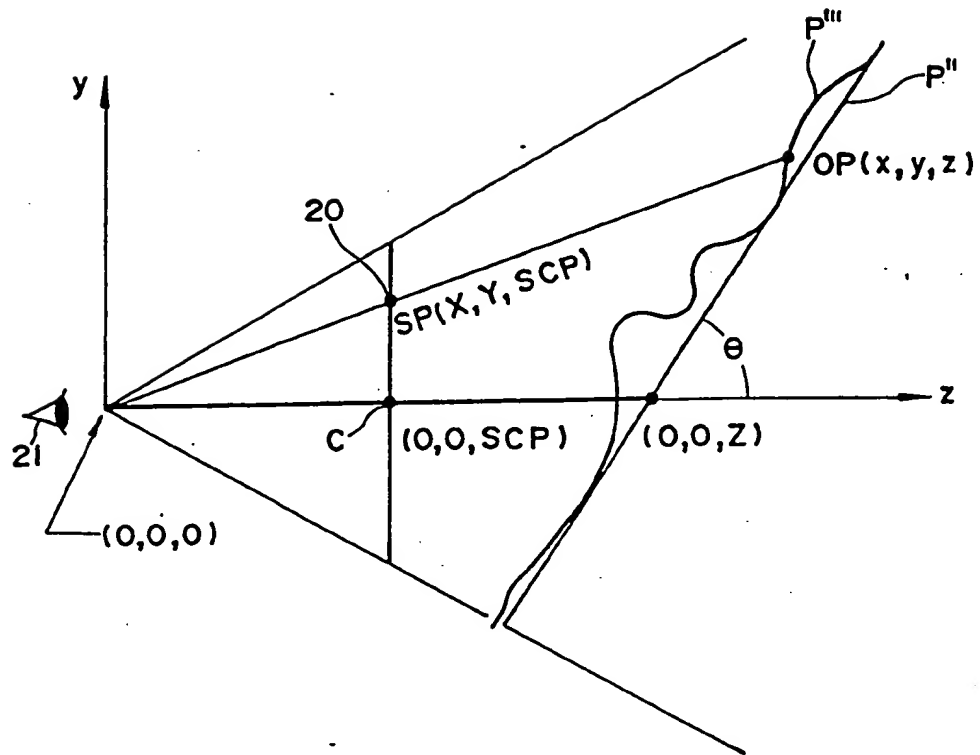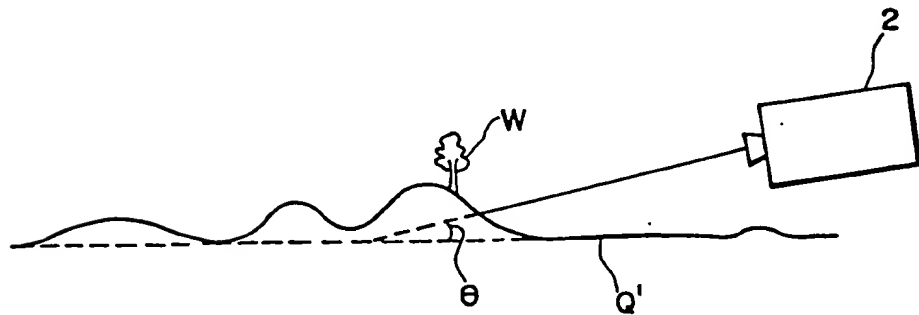
TITLE OF THE INVENTION

IMAGE PROCESSING APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an image processing apparatus and more particularly to an image processing apparatus adapted such that the position of the visual point with respective to the picture image picked up with a television camera and displayed on a monitor is optionally changeable.

Description of the Prior Art

In television broadcasting or the like, to enable an object on the ground to be viewed from a plurality of positions of visual point, it has so far been practiced to dispose the television camera at high places with the use of a scaffold for picture taking or a crane so as to change the image pickup position of the television camera and hence the position of visual point. By relying on such conventional means alone, however, it sometimes becomes impossible to change the position of visual point because the crane or the

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scaffold for picture taking becomes unable to be installed due to the conditions at the place where the picture is taken.

OBJECTS AND SUMMARY OF THE INVENTION

Objects

A primary object of the present invention is to provide an image processing apparatus in which the position of visual point with respect to an object on the ground displayed on a monitor is made optionally changeable without changing the image pickup position of the television camera.

Another object of the present invention is to provide an image processing apparatus in which unnaturalness to be produced in the picture image when the position of visual point is moved with respect to the object displayed on a monitor is made correctable.

Summary

To achieve the primary object of the present invention, this invention, in an image processing apparatus in which the position of visual point with respect to the picture image displayed on a monitor is

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movable, produces a model of the picked-up image of a surface of the object in a three-dimensional coordinate system based on the coordinates of picture elements on the image pickup device of the camera and the image pickup angle of the camera with respect to the object, maps the picture data output from the camera onto the model produced as above, and applies rotational transformation to the model with the video data mapped thereon in the three-dimensional coordinate system, and thereupon, displays the model with the picture data mapped thereon.

To achieve the another object of the present invention, this invention, in an image processing apparatus in which the position of visual point with respect to the picture image displayed on a monitor is movable, deforms an area at a desired position in the model produced in a three-dimensional coordinate system based on the coordinates of picture elements on the image pickup device of the camera and the image pickup angle of the camera with respect to the object to thereby corrects the unnaturalness in the displayed picture image.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing an embodiment of means for image processing of the present invention;

FIG. 2 and FIG. 3 are schematic diagrams explaining the principle of production of a planar model in a three-dimensional coordinate system performed in the means for image processing of the present invention;

FIG. 4 is a schematic diagram showing an example of a picture image picked up by the camera in the means for image processing of the present invention;

FIG. 5 is a schematic diagram showing a picture image shown in FIG. 4 with respect to which the position of visual point has been moved in the means for image processing according to the present invention;

FIG. 6 shows schematic diagrams explaining the principle of correction of unnatural portions in the picture image shown in FIG. 5;

FIG. 7 is a schematic diagram showing a picture image after the unnatural portions have been corrected in the picture image shown in FIG. 5;

FIG. 8 and FIG. 9 are schematic diagrams for explaining the principle of production of a model having ups and downs in a three-dimensional coordinate system

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performed in the means for image processing according to the present invention;

FIG. 10 is a schematic diagram for explaining the portion becoming unnatural after the position of visual point has been moved in the means for image processing according to the present invention; and

FIG. 11 is a flow chart for explaining manner of operation in the means for image processing shown in FIG. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Structure of the image processing apparatus 1 according to the present invention will be described below with reference to FIG. 1. An image of an object such as a golf course 3 is picked up by a television camera 2. At this time, the television camera 2 is fixed and the image pickup angle is θ. The image pickup angle is measured by an image pickup angle measuring means 4 and supplied to a planar model producing means 5. The planar model producing means 5 produces a planar model based on the input image pickup angle θ. The data representing the planar model produced by the planar model producing means 5 is supplied to a height information adding means 6. The

height information adding means 6 modifies the data
representing the planar model based on height
information delivered from a height information input
means 7 to thereby produce data representing a model
having ups and downs. The data representing the model
having ups and downs is supplied to a memory controlling
means 8. A video signal output from the television
camera 2 is supplied to an input image memory 9 and
stored therein such that picture elements are each
stored at predetermined addresses. Meanwhile, a visual
point setting means 10 produces visual point setting
data based on visual point controlling data received
from an input means 11 and supplies the visual point
setting data to the memory controlling means 8. A
correction means 12 produces correction data based on
correction control data received from the input means 11
and supplies the correction data to the memory
controlling means 8. The memory controlling means 8,
based on the data representing the model having ups and
downs supplied from the height information adding means
6, the visual point setting data supplied from the
visual point setting means 10, and the correction data
supplied from the correction means 12, produces read
addresses for the input image memory 9 and write

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addresses for an output image memory 13. The read

addresses for the input image memory 9 and write

addresses for the output image memory 13 are

respectively supplied to the input image memory 9 and

output image memory 13, whereby the video signal stored

in the input image memory 9 is read and stored at

predetermined addresses of the output image memory 13.

The video signals read out of the output image memory 13

is supplied to a monitor 14 and displayed on its monitor

screen.

Now, in the image processing apparatus 1 of

the present invention picking up an image of a golf

course 3 or the like with the television camera 2, the

principle of its producing a planar model in a three-

dimensional coordinate system based on the image pickup

angle θ at that time and mapping a video signal output

from the television camera 2 onto the planar model

disposed in the three-dimensional coordinate system will

be described below.

FIG. 2 shows a state, when an image of an

object on a plane P is picked up by a television camera

2 set in the direction perpendicular to the plane P, of

the object on the plane P perspectively transformed onto

the image pickup device (screen 20) of the television

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camera 2. Conversely speaking, the real position of the object whose image is picked up by the television camera 2 is on the plane P located at a specific distance from the screen 20 in the direction opposite to the position of visual point 21. Therefore, when the position OP of the object on the plane P is represented by (x, y, z), the position of visual point 21 is taken as the origin (0, 0, 0), the center C of the screen 20 is represented by (0, 0, SCP), and the position SP of the object perspectively transformed onto the screen 20 is represented by (X, Y, SCP), the relationship between the position OP of the object on the plane P and the position SP of the object perspectively transformed onto the screen 20 is expressed by the following equations

$$X = \frac{SCP * x}{z} , \qquad \qquad \dots \quad (1)$$

$$Y = \frac{SCP * y}{z} . \qquad \qquad \dots \quad (2)$$

Then, a plane P' which is an inclined plane of the plane P shown in FIG. 2 by a predetermined angle as shown in FIG. 3 is considered. Assuming that this plane P' is inclined by an angle θ with respect to x - z plane at position M, the relationship between the position OP of an object on the plane P' and the

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position SP of the object perspectively transformed on the screen 20 is expressed by the following equations

$$X = \frac{SCP * x}{Z + y \cos \theta} , \qquad \ldots \quad (3)$$

$$Y = \frac{SCP * y * \sin \theta}{Z + y \cos \theta} . \qquad \ldots \quad (4)$$

By solving the equations (3) and (4) for x and y, we obtain

$$x = \frac{X * Z + X * y * \cos \theta}{SCP} , \qquad \ldots \quad (5)$$

$$y = \frac{Y * Z}{SCP * \sin \theta - Y * \cos \theta} . \qquad \ldots \quad (6)$$

And then, z becomes

$$z = Z + y * \cos \theta . \qquad \ldots \quad (7)$$

As apparent from equations (5), (6), and (7), by measuring the image pickup angle θ of the television camera 2 with respect to the plane P' at the time when the image of the plane P' is picked up with the television camera 2, and substituting the angle θ and the position (X, Y, SCP) of each picture element of the object perspectively transformed onto the screen 20 into equations (5), (6), and (7), the plane P' in the three-dimensional coordinate system can be calculated. Here,

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Z is the distance from the position of visual point 21 to the position M on the plane P'. This distance is equal to the distance between the point at which the optical axis of the camera 2 intersects with the golf course 3 and the camera. Hereinafter, the plane P' produced as described above will be called "planar model P'".

By assigning video data of picture elements of the object perspectively transformed onto the screen 20 to the corresponding coordinates on the planar model P' produced as described above, the mapping of the video data onto the planar model P' in the three-dimensional coordinate system is achieved. Thus, it is made possible to produce in the three-dimensional coordinate system the planar model P', which is inclined with respect to x - z plane by the angle the same as the image pickup angle θ of the television camera 2 when picking up the image of the object on the plane P and has the video data. The video data mapped onto the planar model P' disposed in the three-dimensional coordinate system is supplied to the monitor 14 shown in FIG. 1 to be displayed thereon.

As described above, by adding arbitrary values, which are mutually associated, to the coordinate

values corresponding to the positions of the picture elements of the planar model P' disposed in the three-dimensional coordinate system, the planar model P' can be rotationally transformed in the three-dimensional coordinate system. And thereby, it is made possible to change the position of visual point with respect to the planar model P' displayed on the monitor 14.

Therefore, even if the image pickup angle θ of the television camera 2 with respect to the golf course 3 is fixed as shown in FIG. 1, the position of visual point with respect to the golf course 3 displayed on the monitor 14 can be changed. Hence, it is made easy to change the position of visual point such that as if the television camera 2 were brought high to pick up the image of the golf course 3 from right above. More particularly, when there is picture information, for example, as shown in FIG. 4 as a picture image picked up by a television camera 2, a picture for which the position of visual point is moved to a place high above as shown in FIG. 5 can be obtained without changing the image pickup angle θ of the television camera 2.

Thus, according to the present invention, the position of visual point can be determined at will and it is thereby made easy to acquire the sense of

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distance.

When the position of visual point is optionally changed as described above, however, since the planar model P' is formed with the object such as the golf course 3 approximated to a plane, those parts that are not lying on the plane P' such as trees W and humans T in the picture image make the image unnatural when the position of visual point is moved.

The state of an image of such an object as a tree W standing on the ground Q picked up with a television camera 2 from a position of visual point 21 as shown in FIG. 6A being displayed on the monitor 14 is shown in FIG. 6B. If, as shown in FIG. 6C, the position of visual point 21 with respect to the object displayed on the monitor 14 is brought to the position above the object as described above, the length of the tree W will be prolonged as shown in FIG. 6D. This is because the condition of the television camera 2 picking up the image of the object as shown in FIG. 6A is nothing but the condition, as shown in FIG. 6C, of its picking up the image of the tree W lying on the ground Q shown in FIG. 6A..

The method to correct the length of the standing tree W or human being T will be described

below. As the means for correction, the technique proposed earlier by the present applicant and described in U. S. Patent No. 4,791,581 is used.

First, an area VCF to be deformed is defined within the planar model P' as shown in FIG. 6C and FIG. 6D. Then, a deformation vector V_i having direction and quantity of deformation is set up. Further, a point of action CP_i indicating the position to apply the deformation and a vector field function F_i are set up. Then, representing the position vector of the planar model P' before the deformation by P_0, the position vector P_N of the planar model P' after the deformation is given by

$$P_N = P_0 + \sum_{i=1}^{N} V_i * F_i(P_{i-1}, CP_i). \quad \ldots (8)$$

The state of the planar model P' deformed as above is shown in FIG. 6E. That is, the tree W is now set upright. Thus, as shown in FIG. 6F, the prolonged state of the tree W is corrected, and thereby, the ground Q and the tree are displayed on the monitor 14 in the same state as that where the television camera 2 is brought to the position right above the tree.

By performing the correction as described above, the picture image having humans T and trees W

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made longer than real size can be corrected and thus the picture as shown in FIG. 7 can be obtained.

Now, referring to FIG. 8, the case where heights h(u, v) of an object such as the ground Q' are given by such an information source as a topographical map will be described. First, as described above, by substituting the image pickup angle θ of the television camera 2 with respect to the ground Q' and the positions (X, Y, SCP) of the picture elements of the object perspectively transformed onto the screen 20 into equations (5), (6) and (7), a planar model P" in the three-dimensional coordinate system is obtained as shown in FIG. 9. Then, the thus produced planar model P" is deformed based on the data h(u, v) representative of the height at an arbitrary position (x, y, z) of the planar model P". The coordinates (x, y, z) of an arbitrary position in the three-dimensional coordinate system of the planar model P" after the deformation are calculated from

$$x = \frac{X * Z + X * y * \cos\theta}{SCP} , \qquad \ldots \quad (9)$$

$$y = \frac{Y * Z}{SCP * \sin\theta - Y * \cos\theta}$$
$$+ h(u, v) * \cos\theta , \qquad \ldots \quad (10)$$

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$$z = Z + y * \cos\theta + h(u, v) * \sin\theta . \quad \cdots \quad (11)$$

These equations can be derived from equations (6) and (7) by adding components along y axis and z axis of the height h(u, v) of the object to their right-hand sides, respectively. By using the above mentioned equations (9), (10), and (11), a model p''' having ups and downs corresponding to the object in the three-dimensional coordinate system as shown in FIG. 9 can be produced. Further, by the use of equations (9), (10), and (11), it is made possible to uniquely associate positions of the picture elements of the object perspectively transformed onto the screen 20 with coordinates of the model p''' having ups and downs. Therefore, by assigning video data of the picture elements of the object perspectively transformed onto the screen 20 to the corresponding coordinates of the model p''' having ups and downs, it is achieved to map the video data onto the model p''' having ups and downs in the three-dimensional coordinate system. Thus, the model p''' having ups and downs which is inclined with respect to x - z plane by the same angle as the image pickup angle θ of the television camera 2 when picking up the image of the object on the ground Q' and has the video data can be produced in the three-dimensional

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coordinate system. The video data of the model p'''
having ups and downs disposed in the three-dimensional
coordinate system is supplied to the monitor 14 shown in
FIG. 1 and displayed on the same.

As described above, by adding optional values
which are mutually associated to the coordinates
corresponding to positions of the picture elements of
the model p''' having ups and downs and disposed in the
three-dimensional coordinate system, the model p'''
having ups and downs and disposed in the three-
dimensional coordinate system can be rotated. That is,
the angle of inclination of the model p''' having ups
and downs with respect to x - z plane can be optionally
changed. Therefore, when the video data of the model
p''' having ups and downs and arranged in the three-
dimensional coordinate system is displayed on the ·
monitor 14, the orientation of the displayed model P'''
having ups and downs can be changed. In other words,
the position of visual point with respect to the model
P''' can be changed.

At the time the position of visual point with
respect to the model P''' having ups and downs is
changed as described above, if there is a tree W on the
ground Q' as shown in FIG. 10, the length of the tree W

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will become too large when the position of visual point is brought high above the same. This is because there are generally not included data expressing heights of trees W in the information of the heights of the ground obtained from a topographical map or the like, and therefore, when producing the model P''' having ups' and downs, the heights of trees W are neglected and they are considered to be lying on the ground having ups and downs.

The length of the tree W becoming too large when the position of visual point is brought high above the same can be corrected in the same way as described above using FIG. 6. First, an area VCF to be deformed is defined in the model P''' having ups and downs. Then, a deformation vector V_i having direction and quantity of deformation is set up. Further, a point of action CP_i indicating the position to apply the deformation and a vector field function F_i are set up. Then, by representing the position vector of the model P''' having ups and downs before the deformation by P_0, the position vector P_N of the model P''' having ups and downs after the deformation is calculated by the use of equation (8). Thereafter, the model P''' having ups and downs is further deformed according to the position

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vector P_N and thereby the length of the tree W can be corrected.

When the heights $h(u, v)$ of the object such as the ground Q' are given by an information source such as a topographical map, by producing a model P''' having ups and downs as described above and mapping the video data onto the same, the heights of the ground after the position of visual point has been changed can be correctly displayed on the monitor 14.

Below will be described manner of operation of the image processing apparatus 1 of the present invention shown in FIG. 1 with reference to FIG. 11.

At step SP1 the image processing apparatus 1 starts to operate.

At step SP2, the image pickup angle measuring means 4 measures the image pickup angle θ of the television camera 2 with respect to the object such as a golf course 3. The image pickup angle θ may also be measured manually by the operator. The image pickup angle θ measured through the image pickup angle measuring means 4 is supplied to the planar model producing means 5.

At step SP3, the planar model producing means 5 produces a planar model P' in the three-dimensional

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coordinate system by substituting the image pickup angle θ and the positions (X, Y, SCP) of the picture elements of the object perspectively transformed onto the image pickup device of the television camera 2 into equations (5), (6), and (7). The data representative of the planar model P' calculated in the planar model producing means 5 is supplied to the height information adding means 6.

At step SP4, it is determined whether or not there is information about the heights (ups and downs) of the golf course 3 or the like. When it is determined that there is the information concerning the heights at step SP4, the data representative of the heights are input through the height information input means 7 to the height information adding means 6 at step SP5. The height information adding means 6 adds the data representing the height to the data representative of the planar model P' calculated in the planar model producing means 5, as indicated in equations (9), (10), and (11). When it is determined that there is no information about the heights at step SP4, the data representative of the planar model P' calculated in the planar model producing means 5 are directly supplied to the memory controlling means 8.

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At step SP6, the memory controlling means 8, based on the data supplied from the height information adding means 6 or the planar model producing means 5, produces read addresses for the input image memory 9 and write addresses for the output image memory 13 and supplies these addresses to the input image memory 9 and output image memory 13, respectively. The video signal supplied from the television camera 2 and stored in the input image memory 9 is read out according to the read addresses supplied from the memory controlling means 8, and written into the output image memory 13 according to the write addresses supplied from the memory controlling means 8. Through this process, video data of picture elements of the object perspectively transformed onto the screen 20 can be assigned to the corresponding coordinates of the planar model P' or the model P''' having ups and downs. This operation is the mapping.

At step SP7, the data representing the deformed area VCF, data representing the deformation vector V_i indicating the direction and quantity of the deformation, and data representing the point of action CP_i indicating the position where the deformation is performed and the vector field function F_i are supplied through the input means 11 to the correction means 12.

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Also, to the same are supplied the data representing the position vector P_0 of the planar model P' before the deformation or the data representing the position vector P_0 of the model P''' having ups and downs before the deformation from the memory controlling means 8. The correction means 12, responsive to the incoming data, calculates the position vector P_N of the planar model P' after the deformation or the position vector P_N of the model P''' having ups and downs after the deformation by the use of equation (8). The data representing the calculated position vector P_N of the planar model P' after the deformation or position vector P_N of the model P''' having ups and downs after the deformation are supplied to the memory controlling means 8. The memory controlling means 8, based on the data representing the position vector P_N supplied from the correction means 12, produces the read addresses for the input image memory 9 and the write addresses for the output image memory 13 and supplies these addresses to the input image memory 9 and the output image memory 13, respectively. The video signal stored in the input image memory 9 is read out again according to the read addresses supplied from the memory controlling means 8 and written into the output image memory 13 according to

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the write addresses supplied from the memory controlling means 8. Through the described process the planar model P' or the model P''' having ups and downs can be adjusted so that the lengths of·the humans T and tress W are corrected.

At step SP8, it is determined whether or not the correction at step SP7 has been completed. The process at this step 8 is performed by the operator determining whether or not the picture image displayed on the monitor 14 has been brought into a desired state.

At step SP9, visual point controlling data is supplied through the input means 11 to the visual point setting means 10, and the visual point setting means 10 in turn adds the values corresponding to the visual point controlling data to the coordinates of the planar model P' or coordinates of the model P''' having ups and downs supplied from the memory controlling means 8 to thereby produce visual point setting data. The visual point setting data is supplied to the memory controlling means 8. The memory controlling means 8, based on the visual point setting data supplied from the visual point setting means 10, produces the read addresses for the input image memory 9 and the write addresses for the output image memory 13 and supplies these addresses to

the input image memory 9 and the output image memory 13, respectively. The video signal stored in the input image memory 9 is read out again according to the read address supplied from the memory controlling means 8 and written into the output image memory 13 according to the write address supplied from the memory controlling means 8. Through the described process, the position of visual point with respect to the planar model P' or the model P''' having ups and downs can be changed.

At step SP10, the operator determines, from the display on the monitor 14, whether or not a desired state is attained as the result of the setting or change of the position of visual point with respect to the planar model performed at step SP9. When the desired state is attained, the process is ended at the following step SP11. That is, the setting of the position of visual point and the correction of the picture image are performed between the operator and the image processing apparatus 1 in an interactive manner.

According to the present invention, even if the image pickup angle of the television camera 2 with respect to the golf course 3 and the like is fixed as shown in FIG. 1, the position of visual point with respect to the golf course 3 displayed on the monitor 14

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can be optionally changed. Therefore, it is made easy
to change the position of visual point such that as if
the television camera 2 were brought high to pick up the
image of the golf course 3 from right above. Thus, the
sense of distance can be easily acquired.

Further, when the heights h(u, v) of the
object such as the golf course are given by such an
information source as a topographical map, the model
P''' having ups and downs is produced as described above
and the video data is mapped thereon, whereby, even if
the position of visual point is changed, the heights of
the ground can be correctly reproduced on the monitor
14.

Although the golf course was used as an
example of the object in the above description of the
embodiment, various other places such as baseball
grounds can of course be used as the object in the
present invention.

Further, a picture image obtained by mapping
image data, which is obtained by picking up the image of
a golf course or the like, onto a planar model produced
by approximating the golf course or the like to a plane
may be combined with a picture image obtained by mapping
image data, which is obtained by picking up the image of

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humans, trees, and the like, onto a planar model produced by approximating the trees, humans, and the like to a plane, and thereby, a model of the golf course or the like having the trees, humans, or the like may be produced in a three-dimensional coordinate system.

WHAT IS CLAIMED IS:

1. An apparatus for processing image capable
of moving the position of visual point with respect to
an image displayed on a monitor (14) comprising:

a. a camera (2) for picking up an image of an
object (3);

b. mapping means (8, 9, 13) for mapping image
data output from said camera (2) onto a model produced
in a three-dimensional coordinate system.

c. transformation means (10, 11) for
rotationally transforming said model with said image
data mapped thereon in said three-dimensional coordinate
system; and

d. a monitor (14) for displaying said model
with said image data mapped thereon, characterized by

e. producing means (5, 6), based on
coordinates of picture elements on the image pickup
device of said camera (2) and the image pickup angle of
said camera (2) with respect to said object (3), for
producing said model representative of a surface of said
object (3) whose image has been picked up in said three-
dimensional coordinate system.

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2. The apparatus for processing image according to claim 1, characterized by

a. measuring means (4) for measuring the image pickup angle of said camera with respect to said object.

3. The apparatus for processing image according to claim 1, characterized by

a. deformation means (11, 12) for deforming a specific portion of said model with said image data mapped thereon.

4. The apparatus for processing image according to claim 1, characterized in that

said producing means (5, 6) has planar model producing means (5) for producing a planar model by approximating to a plane the surface of said object (3) whose image has been picked up based on coordinates of picture elements on the image pickup device of said camera (2) and said image pickup angle and means (6) for modifying said planar model based on data representative of the height of said surface whose image has been picked up.

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5. Apparatus constructed and arranged to operate substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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